ALLOYS FROM RECYCLED ALUMINUM SCRAP CONTAINING HIGH LEVELS OF IRON AND SILICON

Cross-Reference to Related Application

This application is a continuation of U.S. Provisional Patent Application Serial No. 60/464,982, filed April 24, 2003.

Background of the Invention

This invention relates to aluminum alloys obtained from aluminum scrap containing high levels of iron and silicon, the alloys being suitable for use in the production of can ends and can bodies, as well as building and industrial products, and to processes of manufacture thereof.

There has long been an interest in being able to recycle aluminum alloy products, e.g. aluminum cans, for the production of aluminum alloy products. However, the very strict limits on composition and processing for many alloy products severely limits the amount of aluminum scrap that can be used.

For instance, can end alloy is a highly engineered and rigidly controlled AA 5182 alloy. The composition and processing are controlled within strict limits. The important properties are mechanical strength, earing and the ability to be released in a die after forming. For these reasons, practically every aluminum manufacturer uses the same alloy. Attempts to modify the composition have not been successful primarily because the earing and mechanical properties are significantly effected by these changes. The maximum iron allowed in AA 5182 is 0.35% by weight and the maximum silicon allowed is 0.2% by weight.

A similar situation exists in the production of can bodies where a highly engineered and rigidly controlled

alloy AA 3104 is used. Again, the composition and processing are controlled within strict limits to meet the requirement in mechanical strength and earing, with the result that again practically every aluminum manufacturer uses the same alloy. The maximum iron allowed in AA 3104 is 0.8% by weight and the maximum silicon allowed is 0.6% by weight, but these are normally controlled at about 0.4% iron and 0.2% silicon.

Other aluminum alloy products that have required close control of iron and silicon contents are alloys used in building and industrial products. These are typically AA 3105, AA 5052 and AA 5010. For these, the important properties to control are mechanical strength, formability, rollability and scrap compatibility. As a result, in AA 5010 the iron is limited to less than 0.7% by weight and the silicon is limited to less than 0.4% by weight, preferably about 0.35% (± 0.03%) and 0.37% (±0.03%) respectively. For AA 3105 the maximum iron is limited to less than 0.7% and the maximum silicon to less than 0.6%, preferably around 0.55% (± 0.15%) and the maximum of 0.3% respectively. As for AA 5052, it is generally limited to maximum iron content of less than 0.4% and the maximum silicon content of less than 0.25%, preferably around 0.25% (± 0.15%) and a maximum of 0.08% respectively.

Attempts to use higher amounts of iron and silicon in aluminum alloys for the above purposes have been unsuccessful. When the iron content is increased, more of it remains in solution. This has been detrimental as it can change the crystal shape and therefore the anisotropy. The normal crystal structure of aluminum is phase-centered cubic. When an element such as iron remains in solution, some of the aluminum atoms are replaced by iron which is a much larger atom. This results in longer bonds in these

crystals and therefore distorts their shape, causing increased loads during metal processing to final thickness.

Another problem that has been encountered with high levels of iron is precipitation of iron-aluminide particles ($FeAl_3$ or $FeAl_6$). These are large crystals in the order of 10 to 15 microns.

Among patents describing aluminum alloys containing somewhat higher than normal levels of iron and silicon is Furukawa, JP 2000-309839, published November 7, 2000. This relates to an aluminum alloy for resin-coated can bodies which in broadest terms may contain 0.30 - 0.80% silicon and less than 0.70% iron. The objective was to form Mg_2Si crystallites on the surface of aluminum alloy sheets creating aluminum depletion zones resulting in surface depressions. These depressions provide an anchoring effect for the resin coating.

Robertson et al. U.S. Patent 4,282,044, issued August 4, 1981, relates to an aluminum alloy derived in part from scrap and containing 0.1 - 1.0% silicon, 0.1 - 0.90% iron, 0.4 - 1.0% manganese, 1.3 - 2.5% magnesium, 0.005 - 0.4% copper, 0 - 0.2% titanium and the balance aluminum and incidental impurities. This alloy is primarily used for the production of containers.

In Teirlinck et al. U.S. Patent 4,855,107, issued August 8, 1989, an aluminum can stock is described containing 0.8 - 1.8% manganese, 1 - 2% silicon, 0.7 - 3% magnesium, less than 0.7% iron, less than 0.5% copper and less than 0.5% chromium.

Another alloy for producing aluminum sheet and containers containing relatively high amounts of iron and silicon is described in Neufeld et al. U.S. Patent 4,235,646, issued November 25, 1980. This alloy contains 0.1 - 1.0% silicon, 0.1 - 0.9% iron, 0.4 - 1.0% manganese,

1.3 - 2.5% magnesium, 0.05 - 0.4% copper and 0 - 0.2% titanium.

Currently, low grade high iron and high silicon aluminum alloy scrap can only be recycled into foundary alloys. It is an object of the present invention to be able to use these aluminum alloy scrap materials in higher grade products, such as can ends, can bodies and building and industrial products.

Summary of the Invention

The present invention in its broadest aspect relates to aluminum alloys that are variants of AA 3000 and AA 5000 series alloys containing higher than the usual amounts of silicon and iron. Thus, the alloys containing in percentages by weight, more than 0.6 - 2.0% silicon, 0.9 - 2.4% iron, wherein the ratio of the amount of iron to the amount of silicon is in the range of 1.2 - 1.8:1. Other components of the alloys may include 0 - 0.4% copper, 0 - 1.5% manganese, 0 - 5.0% magnesium, 0 - 0.5% zinc, 0 - 3.5% chromium, 0 - 0.1% titanium and the balance aluminum and incidental impurities.

By having the high levels of iron and silicon in the above ratio, it has been found that adequate silicon is left in solution to remove at the time of pre-heat any iron that is not precipitated out during casting operation. In this way the problem of anisotropy is successfully resolved while allowing a composition that includes high levels of iron and silicon.

Also with the alloy composition of this invention the silicon is present at such a level that no $FeAl_3$ is precipitated out during casting, but all iron is precipitated as $Fe_3SiAl_{12}(\alpha)$ particles. These are quite

small particles of 3 to 5 microns and do not interfere with rolling operations.

The ratio of iron to silicon according to the invention is preferably in the range of 1.3 - 1.6:1 and a range of 1.4 - 1.5:1 is most preferred.

The silicon is preferably present in the range of 0.7 - 2.0%, more preferably 0.7 - 1.5%, while the preferred range for iron is 0.9 - 2.0%, with a range of 0.9 - 1.5% being most preferred.

In one particular embodiment of the invention, an alloy is developed as a recycle friendly can end alloy. This alloy contains more than 0.6 - 2.0% silicon, 0.9 - 2.4% iron, wherein the ratio of the amount of iron to the amount of silicon is in the range of 1.2 - 1.8:1, 0 - 0.4% copper, 0.2 - 0.5% manganese, 4 - 5% magnesium, 0 - 0.1% chromium, 0 - 0.1% titanium, 0 - 0.5% zinc and the balance aluminum and incidental impurities.

While using alloys of the above compositions, generally by the time of casting about 0.32% of silicon remains in solution and by the time the alloy reaches 500°C about 0.25% of the silicon remains in solution. Any concentrations above this level are precipitated out. Thus, by choosing appropriate concentrations of silicon it is possible to promote the removal of one precipitated iron from solution, thereby preventing the adverse high iron contents on mechanical properties and earing.

A further embodiment is a recycled friendly aluminum alloy for making can bodies. For this purpose, the alloy contains more than 0.6 - 1.0% silicon, 0.9 - 1.2% iron, wherein the ratio of the amount of iron to the amount of silicon is in the range of 1.2 - 1.8:1, 0 - 0.4% copper, 0.7 - 1.5% manganese, 0.8 - 1.5% magnesium, 0 - 0.50% zinc and the balance aluminum and incidental impurities.

Further embodiments of the invention relate to variants of building and industrial product alloys AA 3105, AA 5052 and AA 5010 suitable for recycling purposes, these variants being capable of withstanding high levels of iron and silicon without an adverse affect on their mechanical properties.

A variant of AA 3105 contains more than 0.6 - 2.0% silicon, 0.9 - 2.4% iron, wherein the ratio of the amount of iron to the amount of silicon is in the range of 1.2 - 1.8:1, 0 - 0.3% copper, 0.3 - 0.8% manganese, 0.2 - 0.8% magnesium, 0 - 0.5% zinc and the balance aluminum and incidental impurities.

A variant of AA 5052 according to the invention contains more than 0.6 - 2.0% silicon, 0.9 - 2.4% iron, wherein the ratio of the amount of iron to the amount of silicon is in the range of 1.2 - 1.8:1, 0 - 0.1% copper, 0 - 0.1% manganese, 2.2 - 2.8% magnesium, 0 - 0.1% zinc, 0.15 - 0.35% chromium and the balance aluminum and incidental impurities.

A variant of AA 5010 according to the invention contains more than 0.6 - 2.0% silicon, 0.9 - 2.4% iron, wherein the ratio of the amount of iron to the amount of silicon is in the range of 1.2 - 1.8:1, 0 - 0.25% copper, 0.1 - 0.3% manganese, 0.2 - 0.6% magnesium, 0 - 0.5% zinc and the balance aluminum and incidental impurities.

For the purposes of this invention scrap may be obtained from sources such as plant scrap, can scrap, consumer scrap, etc. The scrap to be recycled is charged into a furnace to form a melt composition. The initial melt will vary in composition according to the compositions and amounts of the various types of scrap charged in the furnace. This initial melt is then adjusted as necessary to bring the composition within the ranges stated above and

treated as necessary to remove impurities. The alloy composition is then cast e.g. by the direct chill (DC) process into ingots which are formed into sheet products.

Description of the Preferred Embodiments

Example 1

Different aluminum alloy compositions were prepared incorporating higher levels of iron and silicon as is encountered in aluminum scrap, and were tested as to their suitability for making can bodies. The alloys are shown in Table I below (all amounts in percentages by weight):

TABLE I

Alloy	Iron	Silicon	Fe:Si	Manganese	Magnesium	Copper
Control	0.40	0.20	-	0.88	1.20	-
#1	0.90	0.65	1.38	0.88	1.20	0.17
#2	1.00	0.60	1.67	0.60	1.30	-
#3	1.55	1.05	1.48	0.88	1.20	-
#4	1.72	1.20	1.43	0.88	1.20	-

The balance for each alloy was aluminum and incidental impurities.

The alloys were cast into ingots. These ingots were pre-heated at 593°C for 2 hours and hot rolled to a thickness of 0.090". This was subsequently cold rolled in three passes to a sheet having thickness of 0.01040".

The sheet obtained was then subjected to testing to determine its suitability as can stock. The results obtained are shown in Table II below.

TABLE II

Alloy	YS (kpsi)	UTS (kpsi)	Elong (%)	Earing (%)
Control	40.0	44.0	5.0	3.0
#1	41.0	45.2	-	3.8
#2	38.4	42.1	3.3	3.0
#3	38.0	42.8	-	-
#4	37.1	42.0	1.7	-

The Control as well as Alloys #1 and #2 all formed satisfactory 12 oz. cans in a can plant. Alloys #3 and #4 on the other hand, failed to form satisfactory 12 oz. cans. This shows that for the particular conditions encountered in the forming of can bodies there are particular limits in the amounts of silicon and iron that can be used.

It will, however, be noted that the alloys having higher contents of iron and silicon have good strength characteristics making them useful for other products where formability is not critical.